Nature Conservation

Nature Conservation 63: 1–15 (2026)
DOI: 10.3897/natureconservation.63.183768

Research Article

Can pingers mitigate the bycatch of the endangered Black Sea Harbour Porpoise?

Dimitar Popov[1], Galina Meshkova[1], Hristo Dimitrov[2], Marina Panayotova[3]

1 *Green Balkans NGO, 1 Skopie str., Plovdiv 4013, Bulgaria*
2 *Zoology Department, Faculty of Biology, Plovdiv University, 2 Todor Samodumov str., Plovdiv 4000, Bulgaria*
3 *Institute of Oceanology – Bulgarian Academy of Sciences, 40 Parvi May Str., PO Box 152, 9000 Varna, Bulgaria*
Corresponding author: Dimitar Popov (dpopov@greenbalkans.org)

Abstract

Incidental catch in fishing gear, mainly in bottom-set gillnets targeting turbot, is a major mortality factor for the Black Sea harbour porpoise (*Phocoena phocoena relicta*), an endangered endemic subspecies of cetacean. Acoustic deterrent devices or pingers are widely used to mitigate bycatch. Between 2019 and 2022, trials using three different pinger models (Future Oceans 10 kHz, Future Oceans 70 kHz, and PAL Wideband) were conducted in Bulgaria during standard turbot fishing operations. The study encompassed a total of 57 hauls. Data was collected by onboard observers (79% of all hauls) and through self-reporting by fishermen. In 61% of all hauls, bycatch was observed, accounting for 189 cetaceans: 182 harbour porpoises, 5 bottlenose dolphins, and 2 common dolphins. No significant difference in bycatch rates between active and control nets (one haul each per trial) was observed in trials involving Future Oceans 10 kHz (17 trials) and 70 kHz (6 trials) pingers (U test, $p > 0.05$). However, a significant reduction in cetaceans' bycatch of 74% was recorded during the 6 trials conducted with PAL Wideband pingers (U test, $p < 0.05$). We therefore recommend PAL as a suitable bycatch mitigation device to Bulgarian authorities and the General Fisheries Commission of the Mediterranean.

Key words: Black Sea, bottom-set gillnets, cetacean bycatch, *Phocoena phocoena relicta*, pingers

OPEN ACCESS

This article is part of:
Black Sea ecosystem in the spotlight
Edited by Kremena Stefanova, Snejana Moncheva, Ertuğ Düzgüneş, Lyubomir Dimitrov

Academic editor: Kremena Stefanova
Received: 29 December 2025
Accepted: 18 February 2026
Published: 6 March 2026

ZooBank: https://zoobank.org/0E9F53B0-C1B4-42D0-9629-D8D993673D1F

Citation: Popov D, Meshkova G, Dimitrov H, Panayotova M (2026) Can pingers mitigate the bycatch of the endangered Black Sea Harbour Porpoise? Nature Conservation 63: 1–15. https://doi.org/10.3897/natureconservation.63.183768

Copyright: © Dimitar Popov et al.
This is an open access article distributed under terms of the Creative Commons Attribution License (Attribution 4.0 International – CC BY 4.0).

Introduction

Incidental catch (bycatch) in fishing gear is a major threat and significant source of human-induced mortality for small cetaceans globally and in European seas (Read et al. 2006; Dolman et al. 2016). The Black Sea's isolation is one of the main reasons to nominate its populations of cetaceans as belonging to endemic subspecies: the Black Sea harbours porpoise (*Phocoena phocoena relicta* Abel, 1905) (Viaud-Martinez et al. 2007; Chehida et al. 2020), Black Sea bottlenose dolphin (*Tursiops truncatus ponticus* Barabash-Nikiforov, 1940) (Viaud-Martinez et al. 2008), and Black Sea common dolphin (*Delphinus delphis ponticus* Barabash-Nikiforov, 1935) (Amaha 1994). Commercial exploitation of Black Sea cetaceans in the 20th century, which continued until 1983, has significantly depleted their numbers, with estimated takes for that period ranging from 4 to 5 million individuals

(Birkun et al. 1992). The Black Sea harbour porpoise and bottlenose dolphin are listed as 'Endangered' on the IUCN Red List of Endangered Species, and the Black Sea common dolphin is 'Vulnerable' (IUCN 2008; 2008a; IUCN 2012). In marine waters under the jurisdiction of European Union (EU) member states, cetaceans are protected by the EU Habitats Directive 92/43/EEC and the EU Marine Strategy Framework Directive (MSFD) 2008/56/EC.

Despite legal protection, cetaceans in the Black Sea still face numerous threats, including pollution, biological invasions, overfishing, and bycatch in fishing gear (ACCOBAMS 2021). Recent studies on the impact of bycatch in the Black Sea have estimated annual total bycatch levels of harbour porpoises to vary between 11,826 and 20,000 individuals (Birkun et al. 2014; Popov et al. 2023a). The primary source of bycatch for cetaceans in the Black Sea is the turbot gillnet fishery (Radu and Anton 2014; Tonay 2016), which employs bottom-set nets with a minimum stretched mesh size of 400 mm (200 mm x 200 mm).

The Black Sea turbot (*Scophthalmus maximus* Linnaeus, 1758) is the Black Sea's most valuable commercial fish species. Bulgaria, as an EU Member State, complies with the Common Fisheries Policy, which sets an annual quota for fishing turbot in the Black Sea (GSA29). Fishermen apply for a licence yearly. A seasonal ban on turbot fishing is usually in effect during the spawning period from mid-April to mid-June.

Acoustic deterrent devices (pingers) were developed and introduced first in the USA in the 1990s through the Marine Mammal Protection Act. As for European waters, EU's Council Regulation No 812/2004 stipulated measures on cetacean bycatch in fisheries requiring member states to conduct monitoring of bycatch levels and use pingers as a mitigation measure to reduce bycatch impact on certain species and populations of cetaceans. Black Sea fishing grounds are not included in the scope of the Regulation, meaning Bulgaria and Romania, after joining the EU, were not forced to implement it. The Council Regulation No 812/2004 was amended in 2019 when the European Parliament approved Regulation 2019/1241 on the conservation of fishery resources and the protection of marine ecosystems through technical measures. The European Commission's proposal to require the use of pingers in the Black Sea was not taken up (Dolman et al. 2021).

US and EU regulations have similar technical requirements for pingers: an instrument, which when immersed in water, broadcasts a 10 kHz or 20–160 kHz sound at 130–150 dB re 1 µPa at 1m, lasting 300 ms, and repeating every 4 s. Trials in the Black Sea using different pinger models with these characteristics yielded opposing results: Gönener and Bilgin (2009) concluded that Dukane NetMark™ 1000 pingers can be an effective mitigation measure against the bycatch of harbour porpoise, while Bilgin and Köse (2018) found that Aquamark 100 and 200 pingers did not reduce bycatch of harbour porpoise. The current study was conducted from 2019 to 2022 in the Bulgarian turbot fishery and compared three pinger models to assess their effectiveness in mitigating Black Sea harbour porpoise bycatch in bottom-set gillnets.

Materials and methods

Trials of different pinger models were conducted during standard fishing operations in the Bulgarian Back Sea waters, targeting turbot with bottom-set gillnets. Bulgarian fishermen normally fish turbot with gillnets twice a year.

Effort is concentrated during the migration period to spawning grounds and is defined by the longer soaking time of gillnets compared to other basins. The first season occurs in spring, during March and April (before 15 April), while the second season occurs in summer, during June (after 15 June) and July. The number of trials was conditioned by the number of available pinger units and their respective tally required to equip a string of nets. Another factor that restricted the number of trials was the temporal overlap of fishing efforts by all involved fishermen. Eight fishing vessels with lengths from 7.6 to 15.8 m, possessing a license to fish turbot, participated in the study. These vessels operated from different ports along the Bulgarian Black Sea coast (Balchik, Nessebar, Primorsko, Tsarevo, and Sinemorets). Fishermen used either monofilament or multifilament nets with individual lengths of 50, 70, and 100 m and mesh size 200 x 200 mm (stretched 400 mm) in accordance with regulations. Each fishing vessel used a different number of nets connected in numerous sets, with individual lengths varying from 800 to 11,480 m. Nets were set at depths between 45 and 94 m. Bycatch was recorded by independent observers (79%) and in some cases (smaller boats with limited capacity) by fishermen (21%).

Three pinger models were tested for their effectiveness in mitigating cetacean bycatch with a focus on the harbour porpoise as the most vulnerable species. Devices were available on the market by two companies: Future Oceans (Australia) and F^3 Maritime Technology LTD (Germany). Future Oceans (FO) pingers were of two types: NETGUARD 10 kHz, 132 dB (porpoise) pinger, and NETGUARD 70 kHz, 145 dB (dolphin) pinger (Fig. 1a). Pingers by F^3 Maritime Technology were of the model PAL Wideband 20–160 kHz, 145 dB (Fig. 1b). In contrast to the Future Ocean and other pinger models, the PAL Wideband is positively buoyant, floats, and helps keep the net open. Each PAL remains programmable and allows users to choose from a variety of alerting signals. Signals tested here were first of the type a) main signal of 10, 30, 50, 70, 90, 110, 130, and 150 kHz with 14 repetitions per minute; secondary signal of 12 kHz and 60–150 kHz harmonics with 4 random repetitions per minute and after January 2021 of the type b) used only a single signal identical to the secondary signal of a). Both signals had the same source level.

In 2019, the trials involved 150 units of FO 10 kHz and 50 units of FO 70 kHz. These were fitted on part (30–50%) of the set of nets (active), with the remaining part free of pingers used as control. Spacing for model FO 10 kHz, 132 dB, depending on the individual length of nets, was 70, 100, and 140 m. The producer recommended pingers of that type to be spaced at 100 m. Spacing of the FO 70 kHz, 145 dB in spring was 280 m, while in summer it was 140 m, with the producer's recommendation being 200 m. From 2020 onwards, the configuration was changed, and FO pingers were attached to the full set of nets (active), and control sets were completely free of pingers, situated close to active sets. Spacing was limited to 100 m for FO 10 kHz and 200 m for FO 70 kHz to comply with producers' specifications.

Trials of PAL Wideband pingers were conducted in 2020 (40 and 80 units in spring and summer, respectively) and 2021 (66 units). The manufacturer's recommendation for PAL Wideband pinger spacing was a maximum of 200 m. In our trials, the spacing between PAL pingers was 140 m. No mixed sets were used, but either active or control strings.

Figure 1. a. Future Oceans pinger – both types (10 and 70 kHz) have the same shape and mass, with the only difference being the frequency of the signal; **b.** PAL Wideband pinger.

Given differences in soaking time, length, and most of all height of nets that varied for each fisherman (2, 2.6, and 3 m), we standardised fishing effort. It was calculated as days*km^2 and the bycatch level as ind./days*km^2 (Popov et al. 2023a) using the following formula (1), where days is the duration of fishing effort, and km^2 is the gillnet surface (length*height) area:

$$Bycatch\ level = \frac{number\ of\ individuals}{effort\ (days * km^2)} \quad (1)$$

We used nonparametric tests to detect the significance of the changes in standardised bycatch level per fishing operation. The Pairwise Mann–Whitney U test was applied to test for differences between active and control nets and between the spring and summer seasons. The Kruskal-Wallis H test was used to detect differences among years. Both were performed in the specialized software SPSS. Bycatch reduction was calculated using totals for active and control nets (Gönener and Bilgin 2009; Chladek et al. 2020). Maps were drawn using QGIS 3.16.5.

Results

The study comprised a total of 57 hauls (Suppl. material 1). Bycatch of cetaceans was observed in 61% of all hauls. The share of hauls with bycatch of cetaceans was lower in self-reporting (42%) than those recorded by independent observers (64%). A total of 189 cetaceans were recorded as bycatch: 182 harbour porpoises (96%), 5 bottlenose dolphins (3%), and 2 common dolphins (1%). Soaking time varied between seasons: 10–26 days (mean = 18.19) in spring and 7–26 days (mean = 14.16) in summer. Bycatch rates varied significantly between the years (Kruskal-Wallis H test, $p < 0.05$). Standardized bycatch of cetaceans per unit of effort varied between 0 and 150 ind./days*km^2 (mean = 16.38) in spring. In summer, these numbers varied between 0 and 103.9 ind./days*km^2 (mean = 28.06). Statistical analysis showed no significant difference in bycatch rates between the spring and summer seasons (Mann-Whitney U test, $p > 0.05$). This was valid for the entire four-year period. If only data for 2019–2021 were

analysed, seasonal differences were significant ($p < 0.05$). This finding may be attributed to the unusually high bycatch rates recorded in spring 2022 and the greater number of trials conducted during the spring. The mean spring bycatch rate from 2019 to 2021 was 4.17 ind./days*km^2, but in spring 2022 it increased to 63.16 ind./days*km^2. That represents a rise by a factor of more than 15.

Future Oceans, 10 kHz, 132 dB

This model was available in the highest quantity, with 150 units. Consequently, this led to the highest number of trials: 17. Almost half of the trials were conducted in the first year of the study in 2019. The lengths of the sets of nets involved in the trials varied from 800 to 11,760 m and were distributed spatially in all sectors – northern, central, and southern (Fig. 2). Ten trials were conducted in the spring, and seven in the summer. The spacing of pingers varied between 70 and 140 m, but in most trials, it was 100 m (see Suppl. material 1). Both types of twine – monofilament and multifilament – were used. Trials involved pairs of the same twine nets. In two of the trials in 2019, the fisherman did not comply with the prescribed spacing, and pingers were spaced randomly. As these represented only 11.7% of all trials, it was considered that these would not affect the result of the overall analysis significantly and thus were not excluded from the sample. The highest bycatch values were observed in the summer of 2019 and spring 2022. The total bycatch reduction observed in these 17 trials was 23.16% (Table 1), but this result was not statistically significant (Pairwise Mann-Whitney U test, $p > 0.05$).

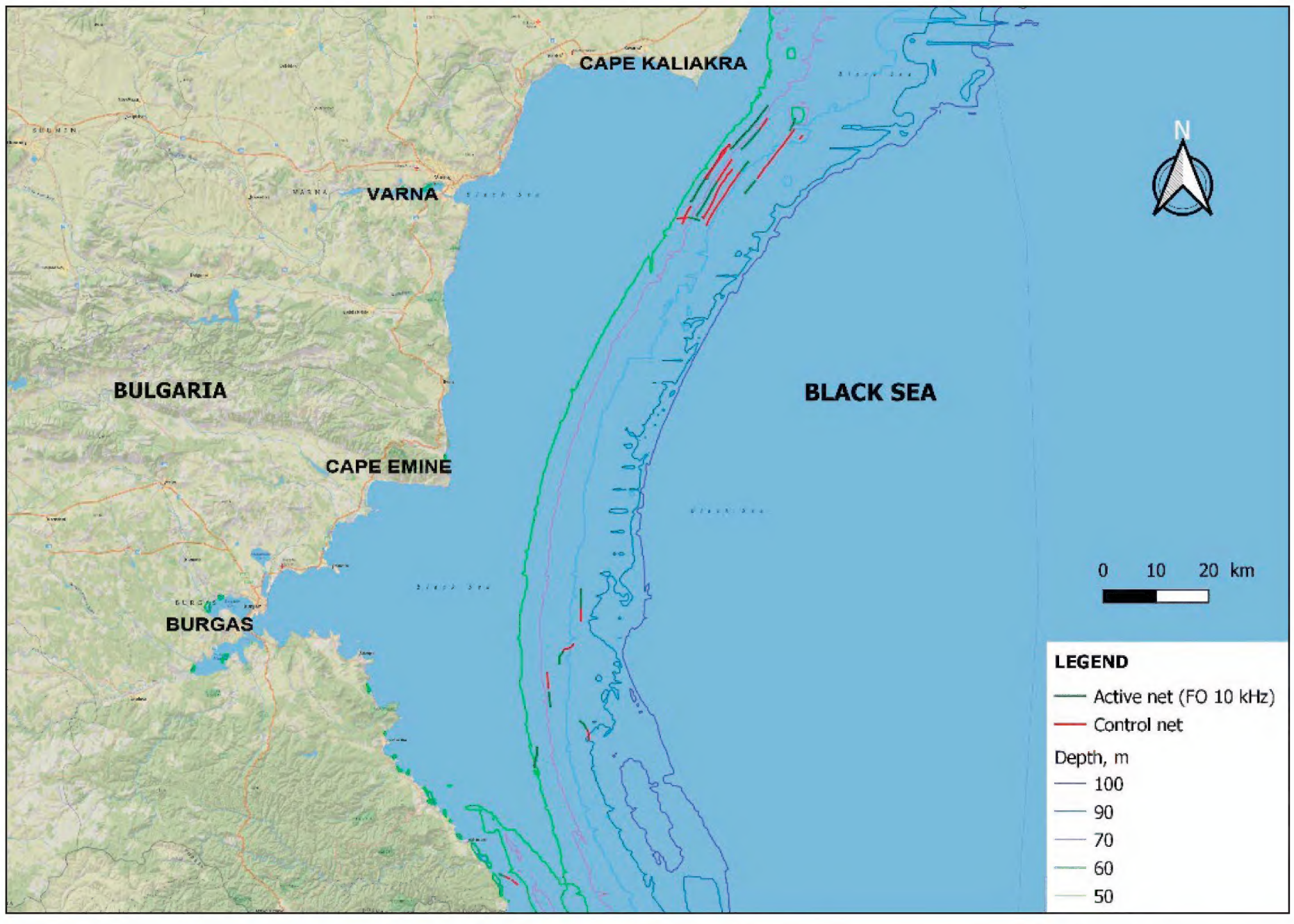

Figure 2. Map of the conducted trials of FO 10 kHz pingers in Bulgarian Black Sea waters from 2019 to 2022.

Table 1. Results of trials that involved pingers Future Oceans, 10 kHz, 132 dB.

FO 10 kHz	Control net	Active net
Year	Bycatch (ind./km²*days)	Bycatch (ind./km²*days)
Spring 2019	7.12	0.00
Spring 2019	2.16	2.38
Spring 2019	0.00	2.29
Spring 2019	0.00	8.16
Summer 2019	35.84	55.56
Summer 2019	103.90	86.58
Summer 2019	16.03	0.00
Summer 2019	-	16.03
Spring 2020	2.42	2.64
Spring 2020	0.00	0.00
Summer 2020	14.88	0.00
Spring 2021	26.46	0.00
Summer 2021	20.25	0.00
Summer 2021	0.00	0.00
Spring 2022	150.00	150.00
Spring 2022	0.00	0.00
Spring 2022	42.11	0.00
Mean	26.32	19.04
Standard Error	10.59	10.01
Median	11	0.00
Total	421.16	323.64
Bycatch reduction	23.16%	

Future Oceans, 70 kHz, 145 dB

This model was initially available in lower quantities, with 50 units in 2019, which were increased to 80 units in subsequent years. The number of trials was six, and most of these were made in the first year of the study. The individual lengths of the sets of nets involved in the trials varied from 1,800 to 6,100 m. Four trials were conducted in the spring and two in the summer. In terms of spatial distribution, these covered all sectors (Fig. 3). The spacing of pingers varied between 140 and 200 m. In a single trial conducted in 2019, the fisherman did not adhere to the prescribed pinger spacing, resulting in a random arrangement. As this involved only one trial, it was considered unlikely to substantially affect the analysis and was therefore retained in the dataset. Notably, no porpoise bycatch was recorded during this trial. The highest bycatch values were observed in the summer of 2019 and spring 2022. No bycatch reduction was observed in these 6 trials, as the total bycatch in active nets was higher than in controls (Table 2). The difference was not statistically significant (Pairwise Mann-Whitney U test, $p > 0.05$), but this cannot compensate for the fact that no reduction in bycatch was recorded. It should also be noted that this pinger model is marketed by the manufacturer as a “dolphin” pinger, and the lack of effectiveness in reducing porpoise bycatch may be attributed to this design specificity.

PAL Wideband, 20–160 kHz, 145 dB

This model was initially available in limited quantity, with 40 units deployed in spring 2020, which was subsequently increased to 80 units for the summer

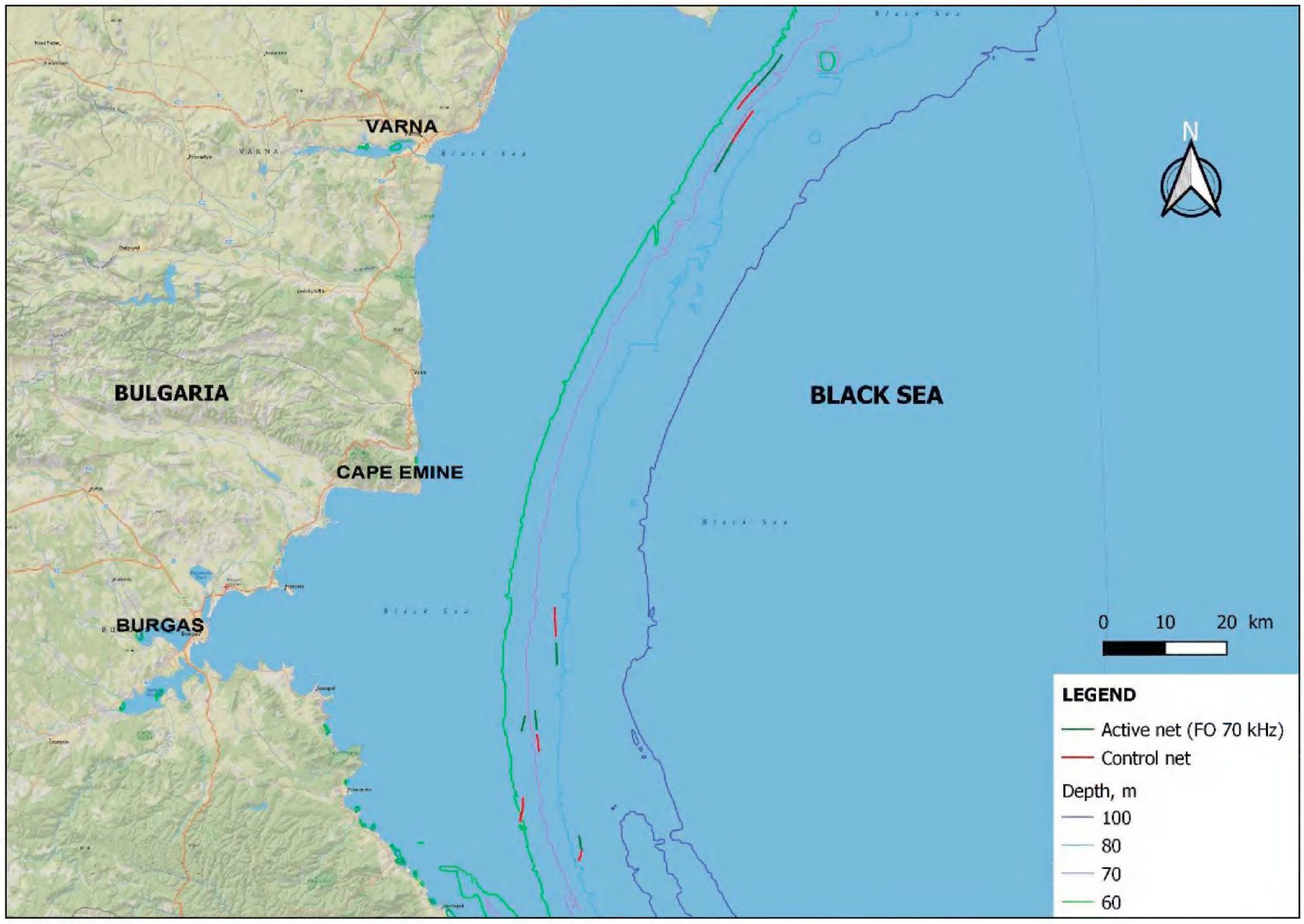

Figure 3. Map of the conducted trials involving FO 70 kHz pingers in 2019–2022.

Table 2. Results of trials that involved pingers Future Oceans, 70 kHz, 145 dB.

FO 70 kHz	Control net	Active net
Year	Bycatch (ind./km²*days)	Bycatch (ind./km²*days)
Spring 2019	0.00	0.00
Spring 2019	0.00	0.00
Summer 2019	78.13	74.40
Summer 2019	16.03	0.00
Spring 2020	0.00	0.00
Spring 2022	0.00	42.11
Mean	15.69	20.53
Standard Error	12.76	12.68
Median	0.00	3.34
Total	94.15	116.51
Bycatch reduction	-23.75%	

season of the same year. In 2021, this number was reduced to 66 units due to losses caused by trawlers that broke part of the active nets in the last trial in 2020. There were six trials in total. All were conducted in the northern part of the Bulgarian shelf at depths between 68 and 82 m (Fig. 4). The lengths of the sets of nets involved in the trials varied from 5,600 to 11,200 m. Two trials were conducted in the spring and four in the summer when bycatch was higher. The spacing of PAL pingers was 140 m. In the summer of 2020, the fisherman extended his operation, allowing four trials (one in spring and three in summer) involving a pair of active

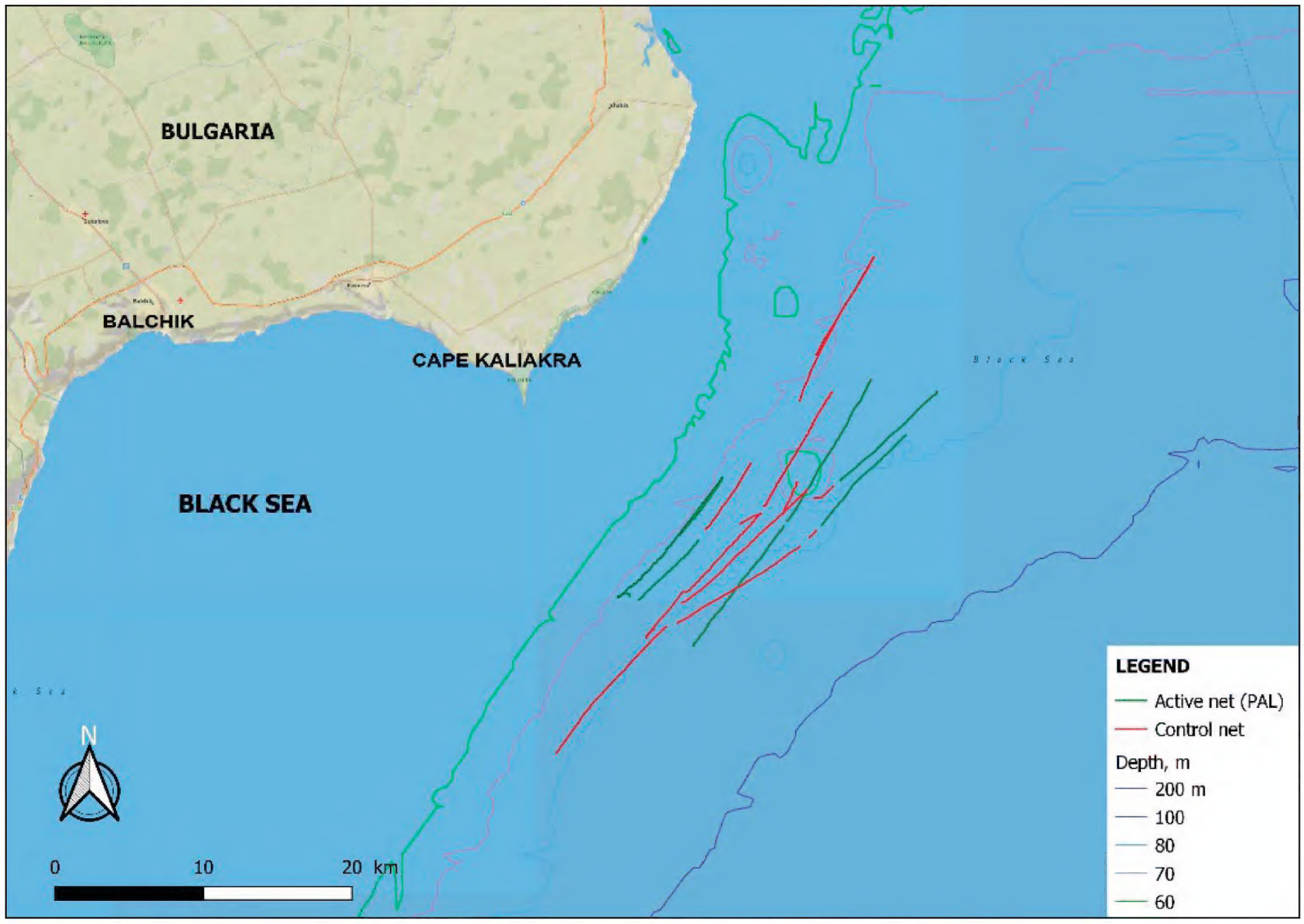

Figure 4. Map of the conducted trials involving PAL Wideband pingers in 2020 and 2021.

Table 3. Results of trials that involved pingers PAL Wideband, 20–160 kHz, 145 dB.

PAL Wideband	Control net	Active net
Year	Bycatch (ind./km²*days)	Bycatch (ind./km²*days)
Spring 2020	2.83	0
Summer 2020	32.18	14.88
Summer 2020	27.55	9.92
Summer 2020	6.87	0
Spring 2021	7.09	0
Summer 2021	17.81	0
Mean	15.72	4.13
Standard Error	4.95	2.69
Median	12.45	0
Total	94.33	24.80
Bycatch reduction	73.71%	

and control strings. In 2021, the fisherman returned to his usual operation that included three strings per season. The lower number of pingers allowed equipping only one shorter string per season, compared to 2020, with the remaining three sets used as controls in each of the two seasons. For the analysis, we used only one of the control strings for each of the seasons in 2021. The highest bycatch values were observed in the summer of 2020 and 2021. The total bycatch reduction observed in these 6 trials was 73.71% (Table 3). This result was statistically significant (Pairwise Mann-Whitney U test, $p < 0.05$). Results improved in 2021,

with zero bycatch recorded in active strings; however, statistical comparison of the two signals revealed no significant difference, likely due to the small sample size. Consequently, the data from trials of both signal types were pooled in the analysis.

Discussion

Of the three pinger models tested, only the PAL Wideband model produced a statistically significant effect, reducing Black Sea harbour porpoise bycatch by 74%. This finding is comparable to the approximately 80% reduction in porpoise bycatch reported in the Baltic Sea during initial trials of the original Porpoise Alerting Device conducted between 2014 and 2016 (Chladek et al. 2020). However, Chladek et al. (2020) used a slightly different approach: they tested the Porpoise-PAL emitting 133 kHz synthetic harbour porpoise communication signals closely resembling those of the Baltic Sea porpoise population. PALs were spaced < 210 m apart from each other. In total, 3,094 net strings set during 929 trips were analysed, and 19 harbour porpoises were bycaught in control strings, while 5 harbour porpoises were bycaught in strings equipped with PALs. PAL effectiveness seems to be increased by reducing device spacing to < 200 m (17 bycatches in control, 3 in PAL strings; mean bycatch reduction 80.1%). In our study, the sample size was considerably smaller, comprising only six trials across 13 trips, yet the total number of porpoises bycaught was higher. This can be attributed to the higher density of the species in Bulgarian Black Sea waters (Popov et al. 2023b) compared to the German Baltic Sea (Benke et al. 2014). We also reduced PAL spacing to 140 m – a factor that seems to increase the effectiveness of these devices. In our study, the distance between active and control net strings ranged from 500 to 1,800 m.

Although some bycatch reduction was observed with the FO 10 kHz pingers on monofilament nets in 2019 and 2020, these effects were not confirmed in subsequent years. The results of our FO 10 kHz trials contrast with earlier experiments in Bulgarian waters, which reported a 100% reduction in bycatch in active nets (Zaharieva 2020). Several factors may explain this discrepancy. Earlier trials involved shorter net sets with total lengths of approximately 1,000 m, whereas in our study, net lengths ranged from 800 to 11,480 m. Net length has been identified as the only factor moderately correlated with bycatch levels in a separate Black Sea survey (Popov et al. 2023a). Additionally, previous trials were conducted exclusively in spring, when overall bycatch was lower. The earlier study included only six trials, whereas our study involved 17 trials, providing greater statistical power.

The results from the current trials of both Future Oceans pinger models differed substantially from most reported outcomes of pinger use for harbour porpoise bycatch mitigation worldwide. In the Pacific Ocean, along the western coast of Washington State (USA), reductions in bycatch ranged from 85% to 97% across different years (Gearin et al. 2000). Along the Atlantic coast of the USA, a reduction of 92% was observed (Kraus et al. 1997). In the central part of the southern Black Sea coast, around Sinop in Türkiye, the use of Dukane NetMark 1000 pinger (a 10 kHz pinger with significant harmonics up to 100 kHz) accounted for a decrease by 98% in harbour porpoise bycatch in bottom-set gillnets targeting turbot (Gönener and Bilgin 2009). The same model has reportedly reduced the bycatch of harbour porpoises in the Atlantic Ocean around Ireland by 87% (SMRU 2001) and by 77% in the Bay of Fundy, Canada (Trippel et al. 1999).

The results obtained in the current study for Future Oceans pingers to some extent coincide with the trials of two other models of pingers (AquaMark 100 (20–160 kHz) and 200 (5–160 kHz), 145 dB) in the eastern Turkish waters of the Black Sea around Rize (Bilgin and Köse 2018). The lack of effectiveness was attributed to both biotic and abiotic factors in the marine environment, as well as technical parameters of the devices, including frequency and signal strength. AquaMark 100 has been successfully used in Danish waters of the North Sea, where bycatch reduction was 78% when the distance between pingers was 585 m and 100% when it was reduced to 455 m (Larsen and Krog 2007).

A review of pinger use for mitigating harbour porpoise bycatch in gillnets along the northeastern coast of the USA indicated that non-compliance with the recommended pinger spacing or device malfunctions were the primary causes of reduced bycatch mitigation. In some cases, the bycatch rate was even higher when compared to nets without pingers (Palka et al. 2008). This was explained by the detection of such zones by porpoises as an end of the obstacle (in that case, a net) indicated acoustically by the pingers. In our study, conditions that could lead to this issue were present in both the 10 kHz and 70 kHz Future Ocean pinger trials in 2019, as portions of the net sets were equipped with pingers while the remaining sections served as controls. However, no concentrations of bycaught porpoises were observed in the border section of the set where active and control nets were connected, indicating that this effect was not the cause of the high bycatch rates in our case.

The effectiveness of only one of the pinger models (PAL Wideband) can be explained by the wider frequency band (between 10 and 150 kHz) programmed in this model. In comparison, two FO models deployed a single main frequency – either 10 or 70 kHz. Kastelein et al. (2015) found that the best hearing range of porpoises is 13 to 140 kHz, with maximum sensitivity at 125 kHz. Furthermore, reduced sensitivity was detected at 32 and 63 kHz, and it fell below 16 kHz. Temporal loss of hearing or decreased hearing ability may be another reason. Mass infestation by the parasitic nematode *Stenurus minor* in the Black Sea harbour porpoise's internal ear is a well-documented cause for loss of hearing (Delamure 1955; Kleinenberg 1956). Another hypothesis that needs further investigation is the acoustic activity and feeding behaviour of the Black Sea harbour porpoise. Different populations of harbour porpoises exhibit different echolocation characteristics, which may enable the development of diverse communication signals (Kyhn et al. 2013; Benke et al. 2014). This was the reason why we tested PAL Wideband pingers in our trials, not the original PAL that deploys the alert signal from the Baltic harbour porpoise. Habituation is another factor that needs to be further investigated through a long-term survey of the same fishing grounds, as we did not have the opportunity to do so in the current survey.

Over the four-year study period, we conducted trials involving three pinger models from two manufacturers, all of which are commercially available. The study area's importance and its high density of porpoises (Paiu et al. 2024) were preconditions for obtaining statistically significant results, even with a relatively small sample size. The high frequency of porpoise bycatch during the observed hauls indicates that our trials were highly representative. Based on the observed statistically significant 74% reduction in bycatch achieved through the use of PAL Wideband pingers, a recommendation was submitted to the national authorities, namely the Ministry of Environment and Water and the Executive Agency

for Fisheries and Aquaculture in Bulgaria. Results have also been presented to international organizations: Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area (ACCOBAMS), International Council for the Exploration of the Sea (ICES), and the General Fisheries Commission of the Mediterranean (GFCM) of the United Nations Food and Agriculture Programme (FAO). Among all these stakeholders, GFCM has taken the opportunity to conduct a large-scale trial of PAL Wideband pingers in the Black Sea in 2023 and 2024 through the CetaByM pilot project. Across 95 trials in Bulgaria, Romania, and Türkiye, these devices reduced the incidental catch of harbour porpoise by 69% without affecting turbot catches (FAO 2025). A total of 47 porpoises were bycaught during the trials, with 36 in control nets and 11 in active nets. In Bulgarian waters, where 15 trials took place, 21 porpoises were recorded in control nets, compared to only five in PAL-equipped nets, yielding encouraging results. The significance of Bulgarian waters as a critical habitat for the Black Sea harbour porpoise was further highlighted by the fact that 55% of all bycaught porpoises during the CetaByM project were recorded in the trials conducted in Bulgaria, which accounted for 16% of all trials.

The urgent implementation of a basin-wide Black Sea harbour porpoise Conservation Plan, mandating the use of PAL Wideband pingers in the turbot fishery, is essential for the effective conservation of this threatened subspecies across all Black Sea countries. Effective control and monitoring to ensure compliance with pinger spacing and placement requirements are critical to achieving the plan's objectives. Implementation will require dedicated funding, with the EU Maritime and Fisheries Fund appearing as the most appropriate source for EU member states in the Black Sea – Bulgaria and Romania. Inclusion of cetacean bycatch mitigation measures within this funding mechanism is necessary. The financial resources required for widespread pinger deployment would constitute only a small fraction of the fund's investments in fishing infrastructure, such as ports, equipment, and vessels. Moreover, public concern regarding the sustainability of ocean resource exploitation supports the appropriateness of such an investment. However, as the remaining four countries bordering the Black Sea are non-EU members, national and regional financial contributions and support will also be necessary.

Conclusions

Conservation efforts for the harbour porpoise in European waters are failing, despite the designation of a high conservation status for its regional populations (Carlén et al. 2021). Bycatch constitutes a key criterion in assessments of conservation status under the EU Habitats Directive and of environmental status under the MSFD. Recent basin-wide estimates of annual bycatch of the Black Sea harbour porpoise are consistent with previous studies and raise serious concerns regarding the long-term viability of this subspecies, which is listed on the IUCN Red List (Popov et al. 2023a). Urgent bycatch mitigation actions are therefore required to reduce the substantial impact of this human-induced mortality.

Mitigation could be implemented through the spatio-temporal closure of high-risk fisheries in areas of high harbour porpoise density, as well as through the adoption of alternative or modified fishing gear, including the use of acoustic deterrent devices (pingers). Among these mitigation measures, the deployment of effective pingers supported by an appropriate funding mechanism

seems the most agreeable from a multifaceted perspective. Trials conducted over four years evaluated three commercially available pinger models, of which only one (PAL Wideband) proved effective; this finding was subsequently confirmed in a larger-scale trial (FAO 2025).

These results address the question posed in the paper's title and underscore that not all pingers are effective in mitigating Black Sea harbour porpoise bycatch in bottom-set gillnets targeting turbot. This finding should be explicitly considered when designing targeted and effective bycatch mitigation strategies in the Black Sea. Only coordinated and timely action by all range states and relevant stakeholders can ensure the achievement of conservation objectives for the Black Sea harbour porpoise and prevent outcomes similar to those observed in closely related populations, such as the Baltic Proper harbour porpoise and the vaquita (*Phocoena sinus*) in Mexico.

Acknowledgments

We thank the onboard observers Gradimir Gradev, Polina Hristova, Nikolay Davidkov, Diyan Rusev, and Hristina Klisurova. Without their invaluable support, this study would not have been possible. We are grateful to the fishermen involved in this study. We thank our funders who made that study a reality: New England Aquarium, ACCOBAMS Supplementary Conservation Fund, and OceanCare (Switzerland). We are grateful to Prof. Boris Culik (F^3 Maritime Technology) for providing PAL Wideband pingers that enabled their trials in the Black Sea and for his advice in designing this study.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

No use of AI was reported.

Funding

This research was funded by the New England Aquarium, Boston, USA under NOAA Award #NA17NMF0080321; the European Union through the CeNoBS project, Agreement 110661/2018/794677/SUB/ENV.C2; ACCOBAMS Supplementary Conservation Fund, MoU 14/2019/FAC.

Author contributions

Conceptualisation: D.P. and M.P. Methodology: D.P. and M.P. Software: D.P. Validation: M.P. Formal analysis: D.P. and M.P. Investigation: D.P., G.M., M.P., and H.D. Resources: D.P., G.M., and H.D. Data curation: D.P. and G.M. Writing – original draft: D.P., G.M., and M.P. Writing – review and editing: H.D., M.P., D.P., and G.M. Visualisation: D.P. Supervision: M.P. and H.D. Project administration: D.P. Funding Acquisition: D.P.

Author ORCIDs

Dimitar Popov https://orcid.org/0000-0003-1873-8815
Galina Meshkova https://orcid.org/0009-0003-4901-3822
Hristo Dimitrov https://orcid.org/0000-0001-5421-9903
Marina Panayotova https://orcid.org/0000-0002-8291-8872

Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

References

ACCOBAMS (2021) Conserving Whales, Dolphins and Porpoises in the Mediterranean Sea, Black Sea and adjacent areas: an ACCOBAMS status report. ACCOBAMS, Monaco.

Amaha A (1994) Geographic variation of the Common Dolphin, *Delphinus delphis* (Odontoceti: Delphinidae). PhD Thesis, Tokyo University of Fisheries, Japan.

Benke H, Bräger S, Dähne M, Gallus A, Hansen S, Honnef CG, Jabbusch M, Koblitz JC, Krügel K, Liebschner A, Narberhaus I, Verfuß UK (2014) Baltic Sea harbour porpoise populations: Status and conservation needs derived from recent survey results. Marine Ecology Progress Series 495: 275–290. https://doi.org/10.3354/meps10538

Bilgin S, Köse Ö (2018) Testing two types of acoustic deterrent devices (pingers) to reduce harbour porpoise, *Phocoena phocoena* (Cetacea: Phocoenidae), bycatch in turbot (*Psetta maxima*) set gillnet fishery in the Black Sea, Turkey. Cahiers de Biologie Marine 59: 473–479. https://doi.org/10.21411/CBM.A.D5B58D5B

Birkun AA Jr, Krivokhizhin SV, Shavtsky AB, Miloserdova NA, Radygin GYu, Pavlov VV, Nikitina VN, Gol'din EB, Artov AM, Suremkina AYu, Zhivkova EP, Plebansky VS (1992) Present status and future of Black Sea dolphins. In: Evans PGHG (Ed.) European research on cetaceans 6 (Proceedings of 6th Annual Conference of the European Cetacean Society, San Remo, Italy, 20–22 Feb 1992). ECS, Cambridge, England, 47–53.

Birkun A Jr, Northridge SP, Willsteed EA, James FA, Kilgour C, Lander M, Fitzgerald GD (2014) Studies for carrying out the Common Fisheries Policy: adverse fisheries impacts on cetacean populations in the Black Sea. Final report to the European Commission, Brussels, Belgium, 347 pp.

Carlén I, Nunny L, Simmonds M (2021) Out of Sight, Out of Mind: How Conservation Is Failing European Porpoises. Frontiers in Marine Science 8. https://doi.org/10.3389/fmars.2021.617478

Chehida YB, Thumloup J, Vishnyakova K, Gol'din P, Fontaine MC (2020) Genetic homogeneity in the face of morphological heterogeneity in the harbor porpoise from the Black Sea and adjacent waters (*Phocoena phocoena relicta*). Heredity 124: 469–484. https://doi.org/10.1038/s41437-019-0284-1

Chladek J, Culik B, Kindt-Larsen L, Albertsen CM, von Dorrien C (2020) Synthetic harbour porpoise (*Phocoena phocoena*) communication signals emitted by acoustic alerting device (Porpoise ALert, PAL) significantly reduce their bycatch in western Baltic gillnet fisheries. Fisheries Research 232: 105732. https://doi.org/10.1016/j.fishres.2020.105732

Delamure SL (1955) Helminth fauna of marine mammals in the light of their ecology and phylogeny. USSR Acad. Science Publ. House, Moscow, 517 pp. [in Russian]

Dolman S, Baulch S, Evans PG, Read F, Ritter F (2016) Towards an EU action plan on cetacean bycatch. Marine Policy 72: 67–75. https://doi.org/10.1016/j.marpol.2016.06.020

Dolman SJ, Evans PGH, Ritter F, Simmonds MP, Swabe J (2021) Implications of new technical measures regulation for cetacean bycatch in European waters. Marine Policy 124: 104320. https://doi.org/10.1016/j.marpol.2020.104320

FAO (2025) The State of Mediterranean and Black Sea Fisheries 2025. General Fisheries Commission for the Mediterranean. Rome, Italy. https://doi.org/10.4060/cd7701en

Gearin PJ, Gosho ME, Laake JL, Cooke L, DeLong RL (2000) Experimental testing of acoustic alarms (pingers) to reduce bycatch of harbour porpoise, *Phocoena phocoena*, in the state of Washington. The Journal of Cetacean Research and Management 2: 1–9. https://doi.org/10.47536/jcrm.v2i1.483

Gönener S, Bilgin S (2009) The Effect of Pingers on Harbour Porpoise, *Phocoena phocoena* Bycatch and Fishing Effort in the Turbot Gill Net Fishery in the Turkish Black Sea Coast. Turkish Journal of Fisheries and Aquatic Sciences 9: 151–157. https://doi.org/10.4194/trjfas.2009.0205

IUCN Red List of Threatened Species (2008) Birkun Jr A A *Delphinus delphis* ssp. *ponticus*. The IUCN Red List of Threatened Species 2008: e.T133729A3875256. https://doi.org/10.2305/IUCN.UK.2008.RLTS.T133729A3875256.en

IUCN Red List of Threatened Species (2008a) Birkun Jr A A and Frantzis A *Phocoena phocoena* ssp. *relicta*. The IUCN Red List of Threatened Species 2008: e.T17030A6737111. https://doi.org/10.2305/IUCN.UK.2008.RLTS.T17030A6737111.en

IUCN Red List of Threatened Species (2012) Birkun A *Tursiops truncatus* ssp. *ponticus*. The IUCN Red List of Threatened Species 2008: e.T133714A17771698. https://doi.org/10.2305/IUCN.UK.2012.RLTS.T133714A17771698.en

Kastelein R, Schop J, Hoek L, Covi J (2015) Hearing thresholds of a harbour porpoise (*Phocoena phocoena*) for narrow-band sweeps [(0.12–150 kHz). SEAMARCO Final report 2015-02]. The Journal of the Acoustical Society of America 138: 2508–2512. https://doi.org/10.1121/1.4932024

Kleinenberg SE (1956) Mammals of the Black and Azov Seas: Research experience for biology and hunting. USSR Acad. Science Publ. House, Moscow, 288 pp. [in Russian]

Kraus SD, Read AJ, Solow A, Baldwin K, Spradlin T, Anderson E, Williamson J (1997) Acoustic alarms reduce porpoise mortality. Nature 388: 525. https://doi.org/10.1038/41451

Kyhn LA, Tougaard J, Beedholm K, Jensen FH, Ashe E, Williams R, Madsen PT (2013) Clicking in a Killer whale habitat: Narrow-band, high-frequency biosonar clicks of harbour porpoise (*Phocoena phocoena*) and Dall's porpoise (*Phocoenoides dalli*). PLoS One 8(5). https://doi.org/10.1371/journal.pone.0063763

Larsen F, Krog C (2007) Fishery trials with increased pinger spacing. Paper presented to the meeting of the Scientific Committee of the International Whaling Commission, Anchorage, Alaska, 7–8 May 2007. The International Whaling Commission, Cambridge, UK.

Paiu RM, Cañadas A, Dede A, Meshkova G, Murariu D, Amaha Özturk A, Popov D, Tonay AM, Timofte C, Kopaliani N, Gol'din P, Panigada S (2024) Density and abundance estimates of cetaceans in the Black Sea through aerial surveys (ASI/CeNoBS). Frontiers in Marine Science 11: 1248950. https://doi.org/10.3389/fmars.2024.1248950

Palka DL, Rossman MC, Vanatten A, Orphanides CD (2008) Effect of pingers on harbour porpoise (*Phocoena phocoena*) bycatch in the US Northeast gillnet fishery. The Journal of Cetacean Research and Management 10: 217–226. https://doi.org/10.47536/jcrm.v10i3.638

Popov D, Meshkova G, Vishnyakova K, Ivanchikova J, Paiu M, Timofte C, Amaha Öztürk A, Tonay AM, Dede A, Panayotova M, Düzgüneş E, Gol'din P (2023a) Assessment of the bycatch level for the Black Sea harbour porpoise in the light of new data on population abundance. Frontiers in Marine Science 10: 1119983. https://doi.org/10.3389/fmars.2023.1119983

Popov D, Panayotova M, Bekova R, Dimitrov H, Meshkova G (2023b) Seasonal Abundance, Density and Distribution of Cetaceans in the Bulgarian Black Sea Shelf in 2017. Diversity 15(2): 229. https://doi.org/10.3390/d15020229

Radu G, Anton E (2014) Impact of turbot fishery on cetaceans in the Romanian Black Sea area. Scientia Marina 78: 103–109. https://doi.org/10.3989/scimar.04029.27A

Read AJ, Drinker P, Northridge S (2006) Bycatch of marine mammals in U.S. and global fisheries. Conservation Biology 20(1): 163–169. https://doi.org/10.1111/j.1523-1739.2006.00338.x

Sea Mammal Research Unit SMRU (2001) Reduction of porpoise bycatch in bottom set gillnet fisheries. Report to the European Commission Study Contract 97/095. SMRU, University College Cork, Cornish Fish Producer's Organisation, and Irish South and West Fishermen's Organisation, Cork.

Tonay AM (2016) Estimates of cetacean by-catch in the turbot fishery on the Turkish Western Black Sea Coast in 2007 and 2008. Journal of the Marine Biological Association of the United Kingdom 96(4): 993–998. https://doi.org/10.1017/S0025315416000060

Trippel EA, Strong MB, Terhune JM, Conway JD (1999) Mitigation of harbour porpoise (*Phocoena phocoena*) bycatch in the gillnet fishery in the lower Bay of Fundy. Canadian Journal of Fisheries and Aquatic Sciences 56: 113–123. https://doi.org/10.1139/f98-162

Viaud-Martinez K, Martínez Vergara M, Gol'din P, Ridoux V, Öztürk AA, Öztürk B, Rosel P, Frantzis A, Kommenou A, Bohonak A (2007) Morphological and genetic differentiation of the Black Sea harbour porpoise *Phocoena phocoena*. Marine Ecology Progress Series 338: 281–294. https://doi.org/10.3354/meps338281

Viaud-Martinez KA, Brownell RL, Komnenou A, Bohonak AJ (2008) Genetic isolation and morphological divergence of Black Sea bottlenose dolphins. Biological Conservation 141(6): 1600–1611. https://doi.org/10.1016/j.biocon.2008.04.004

Zaharieva Z (2020) Study and management of conflict between cetaceans and fisheries in Bulgarian Black Sea waters. PhD Thesis (in Bulgarian). Sofia University „St. Kliment Ohridski". Sofia, Bulgaria.

Supplementary material 1

Supplementary data

Authors: Dimitar Popov, Galina Meshkova, Hristo Dimitrov, Marina Panayotova

Data type: xlsx

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/natureconservation.63.183768.suppl1